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A. ÅNGSTRÖM ON "THE ALBEDO OF VARIOUS SURFACES OF GROUND"

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By H. H. KIMBALL

[A review of *Geografiska Annaler*, 1925, II. 4]

The author introduces his paper by the statement that—

A necessary condition that we may be able to form a clear conception of the heat economy of the earth's atmosphere and the circulation of energy within it, is that some fundamental physical properties of the atmosphere and the ground should be really given by measurements. Such properties, for instance, are the transmission of the atmosphere for sun radiation at various latitudes and at various water vapor contents, the solar constant, the convective properties and the radiation of the atmosphere and also the reflection power of the surface of the earth. The last-named property will be the object of our attention in the following paragraphs; we are going to describe a number of measurements which have been made, in the first place, in order to contribute to the fundaments for an evaluation of the average albedo of large surfaces of ground.

The measurements have been made with an Ångström pyranometer,¹ first exposed so as to measure the intensity of the radiation received by a horizontal surface from above (*i*) and then from below (*r*). The instrument is provided with a glass cover that is impervious to radiation of wave-lengths greater than about 4.0μ , but transmits with small loss the direct radiation from the sun and the radiation scattered by the atmosphere that is received diffusely from the sky. The ratio r/i is therefore the albedo of the earth's surface, or the ratio of the intensity of the radiation diffusely reflected from the surface of the earth to the intensity of that received by it.

The pyranometer has been standardized by comparison with an Ångström compensation pyrheliometer, and tested for possible errors due to exposure in different positions. These latter were found to be negligible.

Since the radiation reflected from the surface of the earth, and especially from a surface covered with vegetation, may be of a different quality from that received from the sun and sky, tests were made by means of filters to ascertain if the pyranometer receiving surfaces are selectively absorptive. The tests indicate that this is not the case to a noticeable degree.

The measurements give surprisingly large values for the albedo of different ground surfaces. For example, the value for a field covered with fresh dry grass is from 0.25 to 0.33, or more than double the values heretofore derived from photometric measurements. This difference the author finds is due to the large coefficient of reflection of grass for red and infra-red radiation, which was found by measurement to be 0.45. It is pointed out that if plants have a low reflecting power for short-wave radiation and a high reflecting power for long waves the reverse must be true of their radiating or emissive powers. If this is true, plants would have "a natural safeguard against loss of heat, which under certain circumstances gives rise to killing frosts."

The reflecting power of wet ground was found to be about half that of dry ground, and the difference, while partly due to evaporation, is attributable principally to total reflection in the water films. This diminution in

the reflecting power of wet surfaces, or, conversely, their increased absorbing power, compensates to a considerable extent for the loss of heat by evaporation.

It is also pointed out that the heat expended in evaporation is not a real loss of energy for the earth-air system, since it only means a transport of energy to higher altitudes. Reflection, on the other hand, means a real loss of energy income.

The vertical component of the reflection of sky radiation from a rough water surface measured by the method employed in measuring reflection from the ground was found to be about 10 per cent. The reflection of solar + sky radiation can also be measured by the same method, but the reflection of direct solar radiation alone has been obtained only through computation based upon the above measurements. These computed values agree well with those given by the formula of Fresnel except for altitudes of the sun less than 15° , where the measurements are unreliable. A curve is given showing the per cent of reflection of sunlight for different solar altitudes. The author points out the importance from a climatic standpoint of the high percentage of reflection with low sun, and especially on the sloping shores of considerable bodies of water. This fact has already received attention.

The transmission of solar radiation by green leaves was measured by coating the glass cover of the pyranometer with leaves carefully trimmed and fitted together.

The following table gives the transformation of energy by leaves under different conditions:

	Early summer (leaves with high water content)	Late summer after dry period (leaves with low water content)
	Per cent	Per cent
Reflection.....	19	29
Absorption.....	55.5	38
Transmission.....	25.5	33

Under a thick growth of trees the radiation receipt was found to be as low as 1 to 2 per cent of that received in the open. Therefore, since the reflection from the tops of such trees appears to be only 10 to 15 per cent, most of the incoming radiation must be expended in warming the upper part of the trees; but this heat may be carried away by air currents quite rapidly. On the other hand, the cooling at night would take place principally in the tree tops, and this cold air readily settles to the ground. This explains why in forests we find considerably lower maximum temperatures in summer than in the open, but only slightly higher minimum temperatures.

The coefficients of reflection for different surfaces given in this paper should undoubtedly be considered in connection with investigations in Radiation and Climate.

¹ For description see Mo. Wea. Rev. 47: 795-7, Nov., 1919, and 49: 135-8, Mar., 1921.